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BAFFLING TEST AND CALIBRATION OF ARPA/AFCRL CVF II SPECTROMETER

Frederick Arnold

ARO, Inc.

February 1971

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NOTICES

BAFFLING TEST AND CALIBRATION OF ARPA/AFCRL CVF II SPECTROMETER

Frederick Arnold
ARO, Inc.

FOREWORD

This work was sponsored by the Advanced Research Projects Agency (ARPA) (STO) through the Air Force Cambridge Research Laboratories (AFCRL) (CROR), Bedford, Massachusetts, under Program Element 62301D.

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This technical report has been reviewed and is approved.

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ABSTRACT

Tests were performed in the Aerospace Research Chamber (7V) on the ARPA/AFCRL second-generation, circular variable filter spectrometer. These tests included field of view, relative sensitivity, wavelength calibration, and off-axis rejection measurements. As a result of a previous test and preliminary results of this test, it was decided that further modifications to the sensor were necessary. These included removal of the baffle tubes and other modifications to the optical system to increase sensitivity at the expense of off-axis rejection.

CONTENTS

APPENDIXES

SECTION I
INTRODUCTION

The Air Force Cambridge Research Laboratory (AFCRL) and the Advanced Research Projects Agency are engaged in the development of an infrared spectrometer for studies of the infrared emittance and reflectance of the earth's upper atmosphere. The sensor development work is being carried out by Utah State University and features a liquid-helium-cooled, mercury-doped germanium detector and a rotating, circular variable filter (CVF) for spectral scans in the 4- to 13-μm range. The filter is an interference type with a film of continuously variable thickness. An optical pulse generator is used to correlate filter position with detector output, and the detector output is channeled through series amplifiers providing four output channels with gains of 1, 10, 100, and 1000.

Testing of the first-generation CVF spectrometer, Utah State Model WW-12, was accomplished at AFCRL and also at AEDC (Refs. 1 and 2). The current test was intended to be the final preflight test of the second-generation spectrometer, the Utah State Model HS-1 (Fig. 1, Appendix I), which incorporated mechanical and electronic improvements as well as a set of optical baffle tubes to improve off-axis rejection. Previous testing on this instrument has been accomplished at AEDC (Ref. 3), but noise levels on the two highest gain channels were unacceptably high and additional data on off-axis rejection was required. Modifications to the sensor were accomplished, primarily to reduce microphonic noise, and the sensor was returned to AEDC for additional testing. In addition to off-axis rejection, objectives of the current test were: (1) a check of wavelength calibration, (2) field of view, and (3) relative sensitivity.

SECTION II
APPARATUS

2.1 AEROSPACE RESEARCH CHAMBER (7V)

The Aerospace Research Chamber (7V) (Fig. 2) consists of four integrated systems which are used for testing long wavelength infrared (LWIR) sensors.

2.1.1 Chamber

The 7V is a stainless steel horizontal chamber 7 feet in diam by 12 feet in length with access provided by a 7-ft-diam door on each end of the chamber. A 2-ft-diam by 6-ft-long cylinder has been installed in the east door. Equipped with an isolation valve, this antechamber permits the return of a test article (sensor) to ambient conditions while the main chamber and the LWIR simulator equipment remain at test pressure and temperature.

A liquid-nitrogen-cooled shroud, approximately 74 in. in diam and 12 ft long, lines the chamber and operates at approximately 77°K. Inside the liquid-nitrogen-cooled shroud is a gaseous-helium-cooled liner which is maintained at 20°K. The helium-cooled liner is fabricated from extruded aluminum finned tube material and is 10 ft long with an inner diam of approximately 66 in.

2.1.2 Pumping System

Evacuation of the chamber is accomplished by two 260-liters/sec turbomolecular pumps backed by a lobe-type blower which, in turn, is backed by a 140-cfm mechanical vacuum pump. This "dry" pumping system prevents sensor optical system contamination. Additional pumping in the form of cryopumping is provided by the liquid-nitrogen- and gaseous-helium-cooled liners. The large cryopumping capacity provides the low pressures (10^{-8} torr) at which most of the tests are performed.

2.1.3 Refrigeration System

The liquid nitrogen is supplied from a 13,000-gal storage tank; the boil-off gas is reliquefied and returned to the tank. The gaseous helium may be supplied from one of two 4-kw refrigeration units or from a 1-kw unit. The liquid helium required for sensors under test is provided by an "in-house" helium liquefier unit.

2.1.4 LWIR Target Simulator System

This system consists of a target or source simulator and a solar and earth radiation simulator.

The target or source simulator has the following performance specifications:

Resolution	0.5 milliradians
Field of View	6 x 6 deg
Rate of Motion	0 to 1 deg/sec
Modulation Frequency	100 to 500 Hz
Target Temperature Range	Classified
Irradiance Range	Classified

Background and stray radiation is controlled with helium-cooled baffles as required.

The solar and earth radiation simulator has the following performance specifications:

Beam Diameter	10 ± 1/2 in.	
Angular Displacement (Beam)	0 to 70 deg (in horizontal plane)	
Decollimation Angle	±3 deg max	
Uniformity	±10 percent	
Irradiance (at sensor)		
Solar	Total:	0.14 w/cm^2
	8-14 μm:	1.15×10^{-4} w/cm^2
Earth	Total:	5.6×10^{-4} w/cm^2
	8-14 μm:	2×10^{-5} w/cm^2

2.2 SENSOR INSTALLATION

The sensor was installed in the antechamber with its multi-aperture, sun-shield baffle (see Fig. 1) inserted through an optically tight mating baffle on the chamber liner end plate. The instrument was thermally and electrically insulated from the liner baffle and the antechamber instrument support structure. No practical method was found for electrically isolating the sensor from its liquid-helium supply dewar; therefore, the dewar was isolated from its surroundings. Thus, the sensor, its liquid-helium supply and vent lines inside the antechamber, the liquid-helium penetration flange, transfer line, and dewar were isolated as a unit.

Previous difficulties with off-axis rejection measurements (Ref. 1) were overcome for the current test by revising the sensor mount to provide remote alignment in the vertical plane for the earthshine radiation. Precise prealignment is not possible because of movement during cooldown and because the exact optical axis of the sensor is not known. With X-Y motion of the target blackbody, exact alignment with the optical axis can be obtained by maximizing the sensor signal. However, the solar and earthshine radiation moves only in the horizontal plane. With the addition of the vertical adjustment to the sensor mount, alignment with the earthshine system can also be accomplished by adjusting position for peak sensor output.

2.3 INSTRUMENTATION

The four detector output channels were selectively patched into one channel on an oscillograph, with the filter position reference displayed on a second channel. A two-channel memory oscilloscope was used to monitor detector output during adjustment of chamber parameters, then one or more filter wheel scans of the sensor were recorded on the oscillograph.

SECTION III
RESULTS AND DISCUSSION

3.1 WAVELENGTH CALIBRATION

Since the HS-1 instrument had been dissassembled and reassembled during the time period between the initial calibration at AEDC (Ref. 3) and the calibration which is the subject of this report, it was decided to check the wavelength calibration in the 7V chamber. This was accomplished by means of a filter wheel containing six narrow band filters.

The circular variable filter of the HS-1 instrument was originally calibrated at AFCRL using a Brower spectrometer. The filters in the filter wheel were calibrated at AEDC in the 7V chamber during the test of April 8, 1970, with the aid of the calibrated circular-variable filter. It was found that the narrow band filters have peaks at 4.60, 8.35, 9.50, 10.77, 11.30 and 11.80 μm. An independent measurement of the peak of the longest wavelength filter made at AFCRL yielded a value of 11.89 μm.

The results of the wavelength calibration are presented in Table I, Appendix II. It is seen from the table that the positions of the peaks as determined in this test differ from the calibrated positions of the peaks by less than one resolution element in all six cases. One can, therefore, conclude that within the accuracy of this measurement, disassembling and reassembling the instrument did not affect the wavelength calibration of the instrument.

3.2 FIELD OF VIEW CALIBRATION

The field of view was determined by moving a point source of radiation across the aperture of the instrument. The point source was moved in both the horizontal and the vertical planes, the field of view being defined by the half-power points. Figures 3 through 6 show the results of these measurements at wavelengths of 4.13 and 10.05 μm. Table II gives the field of view as determined from the graphs. Taking the numerical average of the four values in Table II as representing the true field of view of the instrument, it was found that the field of view was 0.270 deg or 2.04 x 10^{-5} steradians.

3.3 RELATIVE SENSITIVITY

The sensitivity of the highest gain channel, G_4, was determined relative to the sensitivity of the next highest gain channel, G_3. The results of this measurement are given in Table III. It is seen from the table that the highest gain channel is a factor of 10 higher than the next highest gain channel. The accuracy of the measurement was limited by noise.

3.4 OFF-AXIS REJECTION

The off-axis rejection was measured using the earthshine simulator and solar beam. The results of these measurements are given in Table IV. The value of these measurements is doubtful because of two factors. First, during the test the signal was peaked by changing the position of the source; this action, however, also focused the beam so that it no longer completely filled the aperture of the instrument. Secondly, the earthshine beam is not strictly collimated (a 4-in.-diam beam becomes a 10-in. beam in a distance of about 12 ft). A laser source with a suitably broad beam would greatly increase the value of off-axis rejection measurements in the case of long, narrow, baffle tubes as used with this instrument.

SECTION IV
CONCLUSIONS

A second series of tests was performed on the ARPA/AFCRL second-generation circular-variable filter spectrometer. The field of view was determined to be 0.27 deg and the wavelength calibration from the previous test was checked and found unchanged. Off-axis rejection was measured and response to a simulated earthshine was found to decrease approximately three orders of magnitude in moving from the optical axis to 3 deg off-axis.

As a result of the initial test (Ref. 3) and preliminary results of this test, it was decided that further modifications to the sensor were necessary. These included removal of the baffle tubes and other modifications to the optical system to increase sensitivity at the expense of off-axis rejection. Thus, the results of Ref. 3 and the current test are not preflight calibrations, and a third test of the HS-1 instrument for preflight calibration has been scheduled.

REFERENCES

1. Condron, T. P. "Post Flight Calibration of the AFCRL CVF Radiometer." Air Force Cambridge Research Laboratories Report, February, 1970.

2. Warner, R. M. "Calibration of AFCRL First Generation CVF Spectrometer." AEDC-TR-70-152, August 1970.

3. Warner, R. M. "Calibration of ARPA/AFCRL Second Generation CVF Spectrometer." AEDC-TR-70-200, September 1970.

APPENDIXES

I. ILLUSTRATIONS
II. TABLES

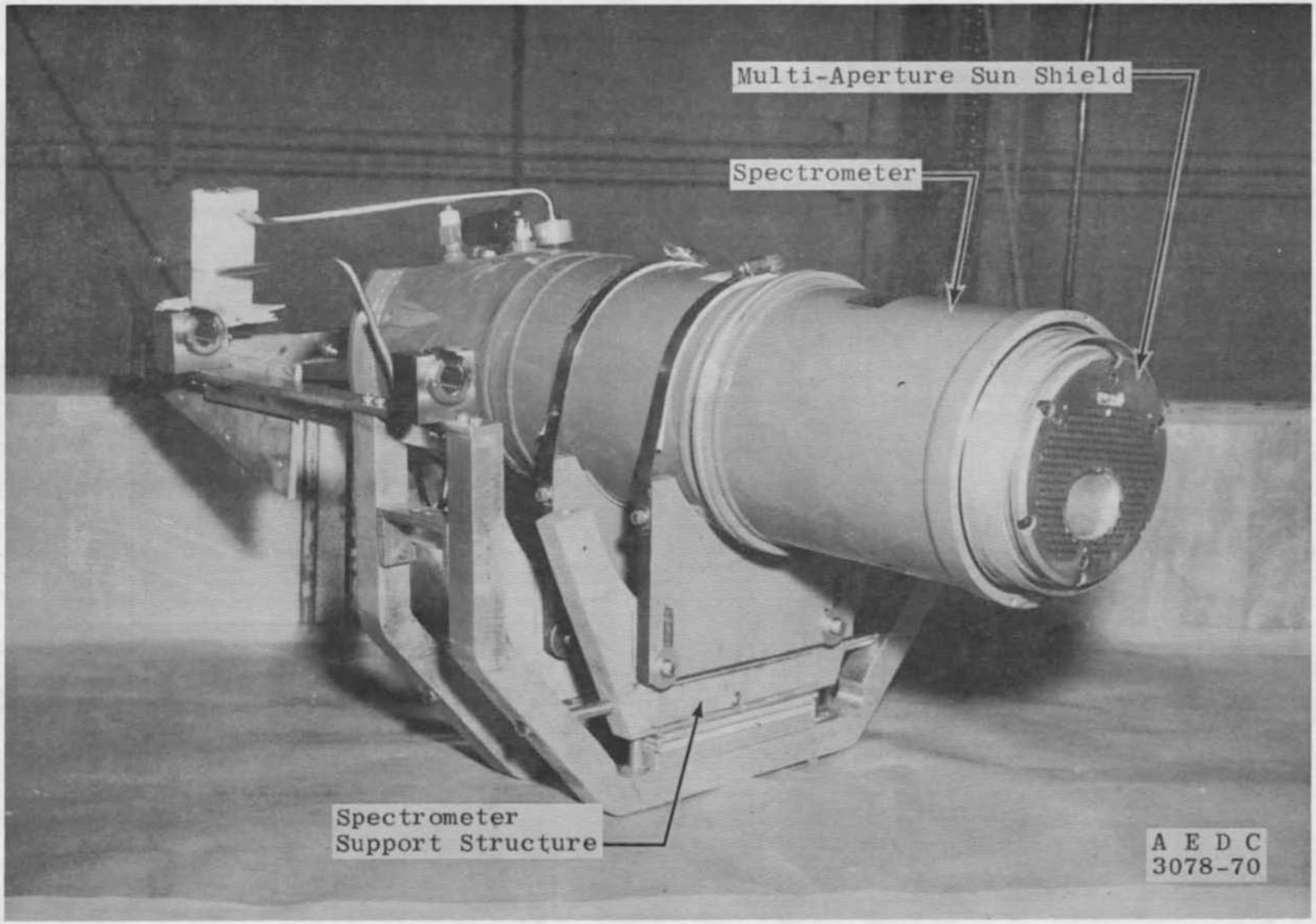

Fig. 1 ARPA/AFCRL Second-Generation CVF Spectrometer

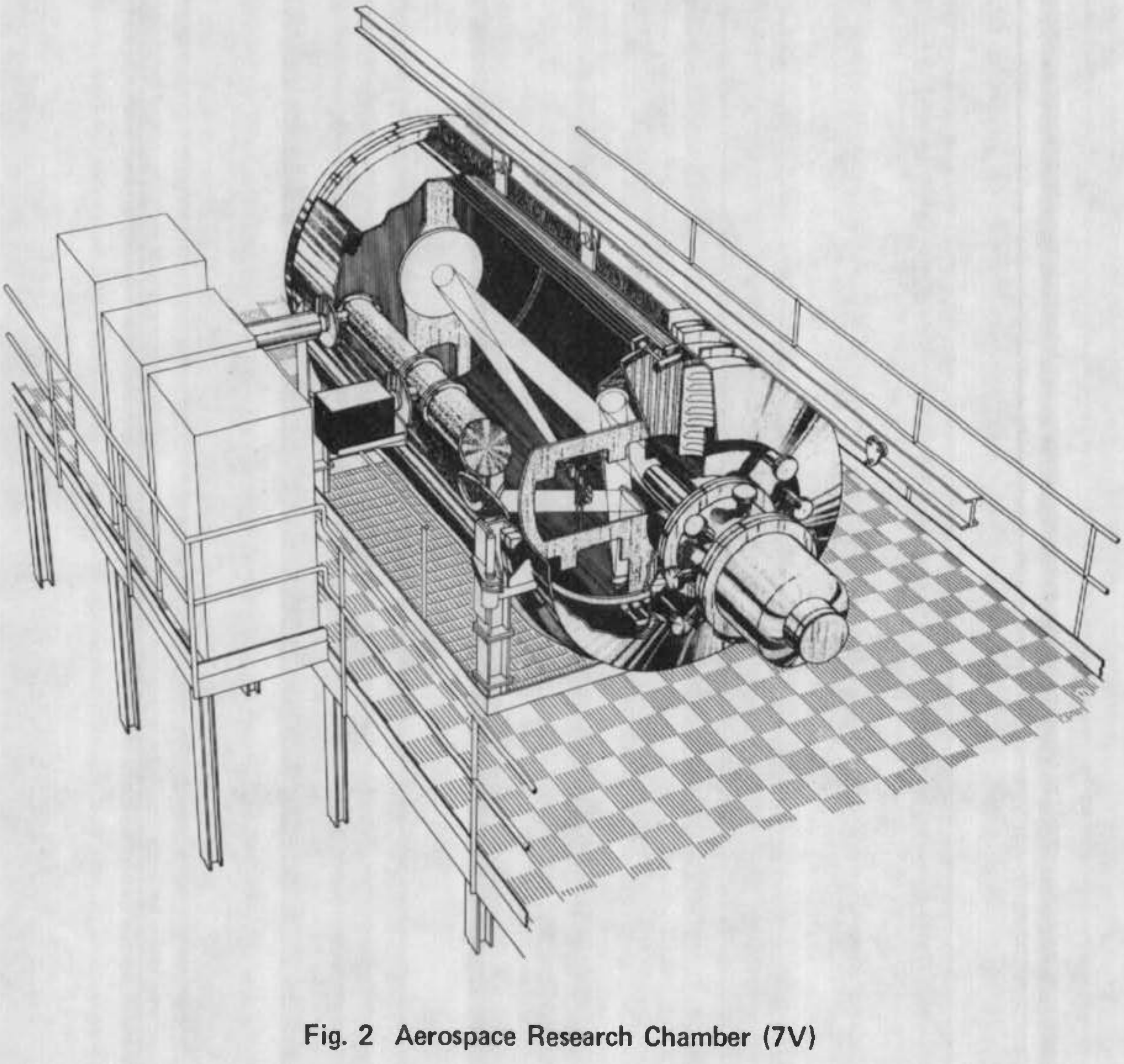

Fig. 2 Aerospace Research Chamber (7V)

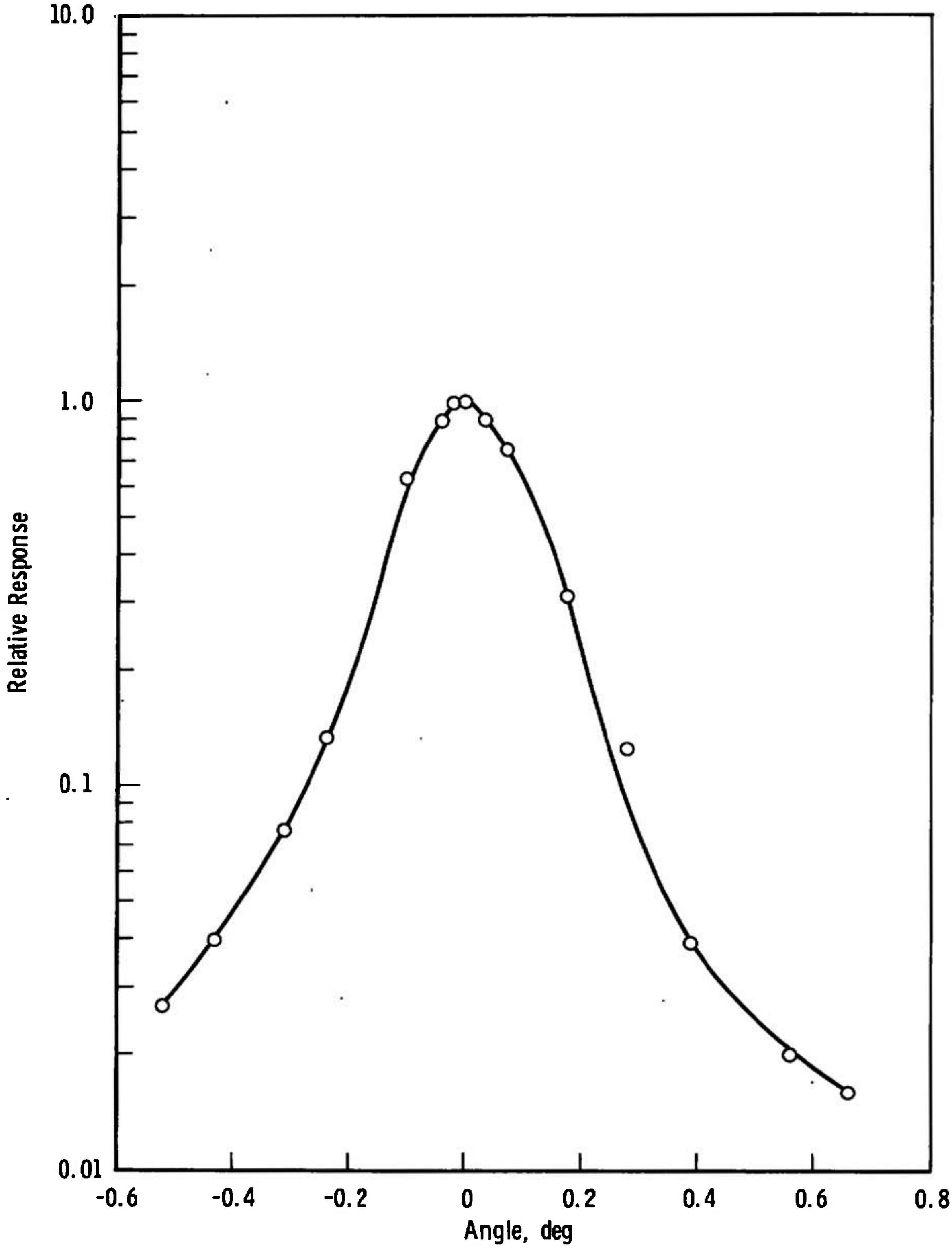

Fig. 3 Angular Response - Horizontal Axis (λ = 10.05 μm)

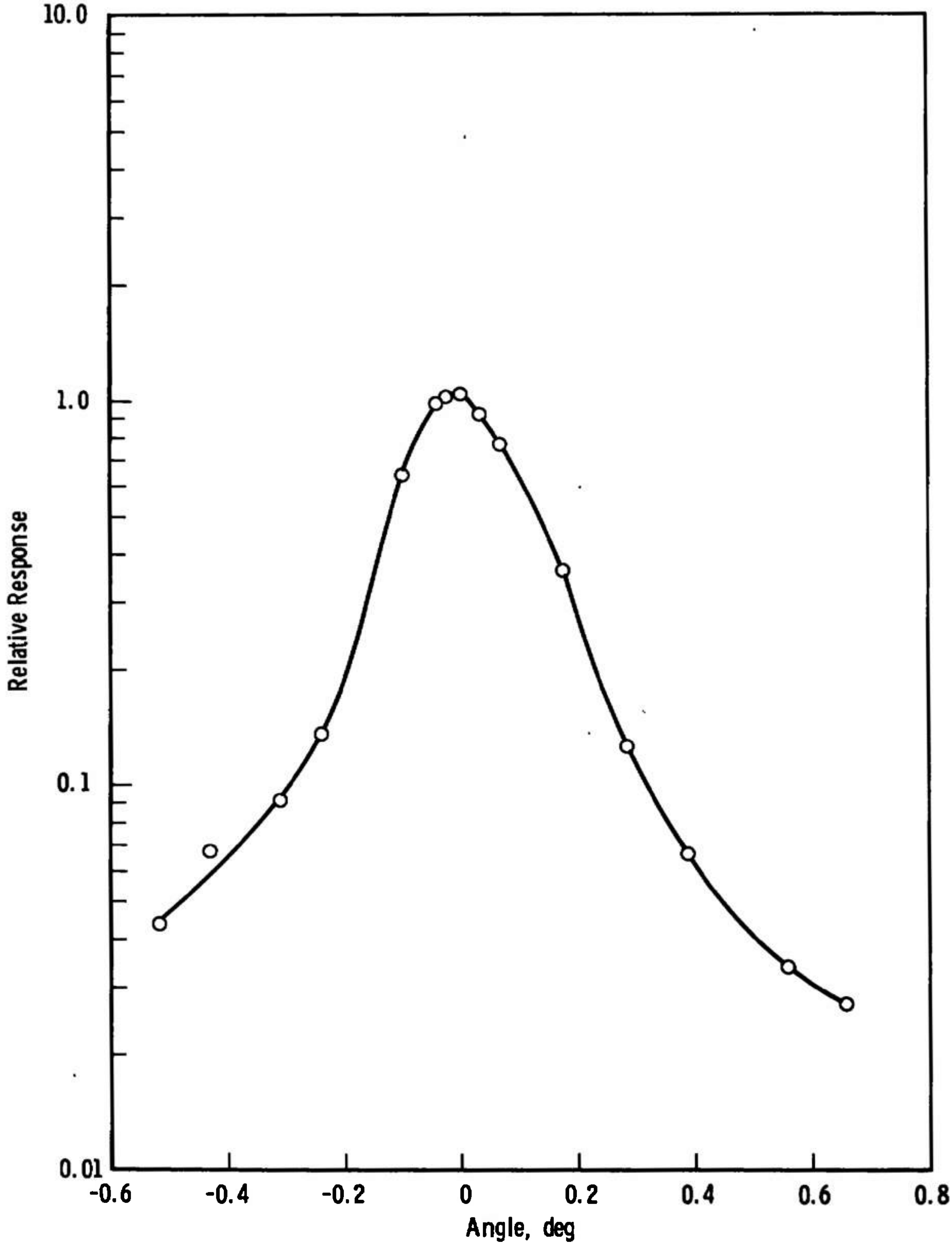

Fig. 4 Angular Response - Horizontal Axis (λ = 4.13 μm)

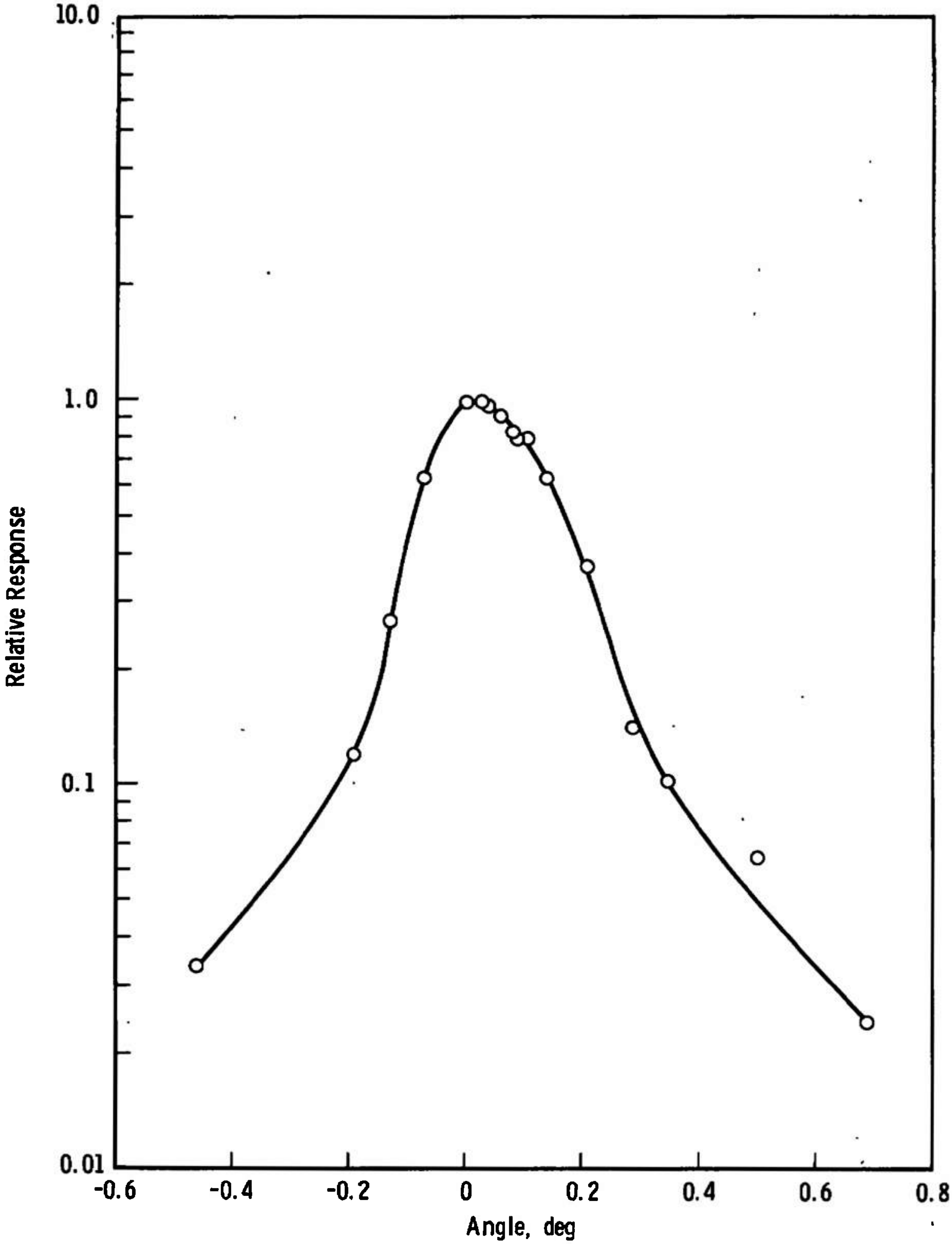

Fig. 5 Angular Response - Vertical Axis (λ = 4.13 μm)

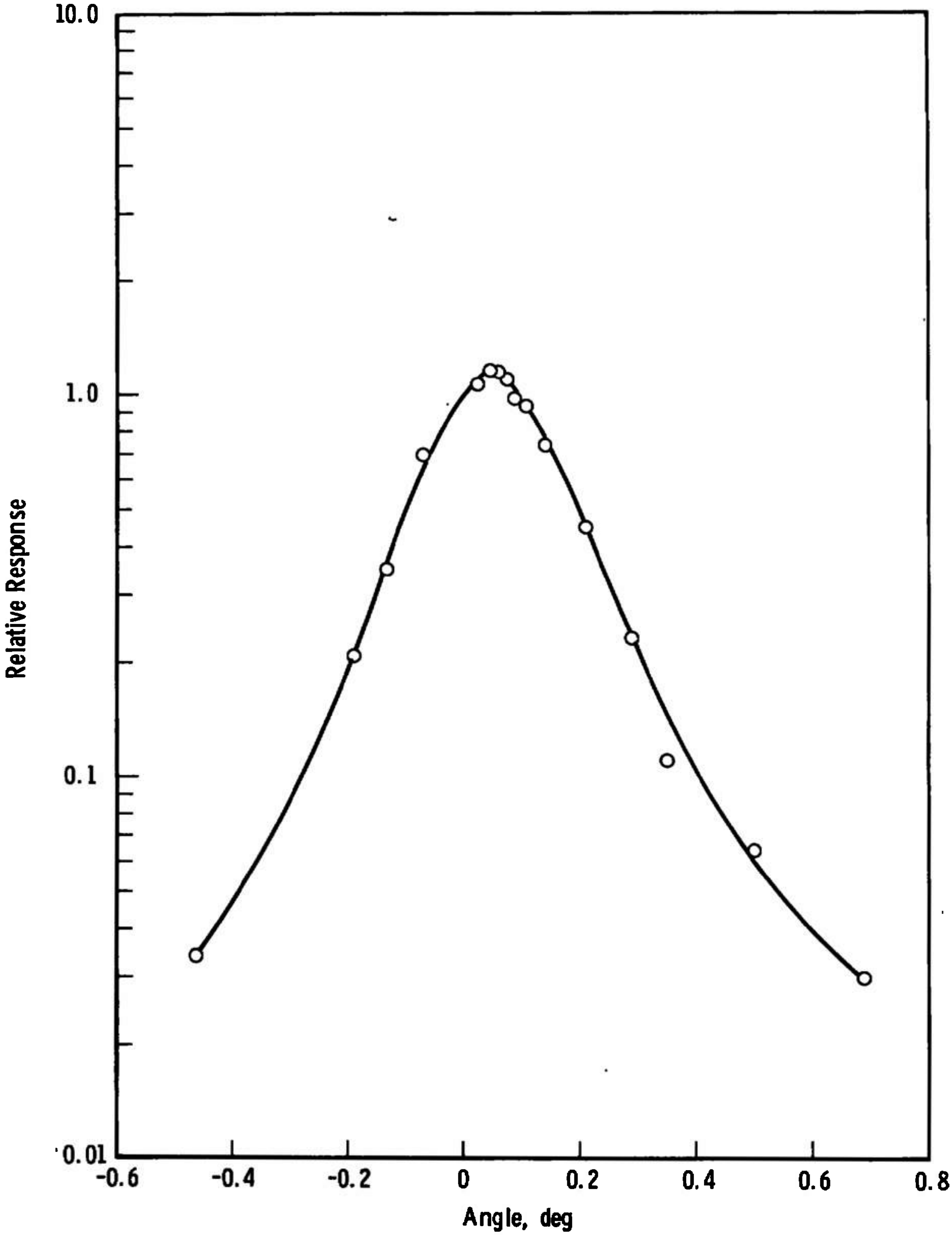

Fig. 6 Angular Response - Vertical Axis (λ = 10.05 μm)

TABLE I
WAVELENGTH CALIBRATION DATA

Calibrated Peak of Narrow Band Filter, μm	Observed Peak, μm	Calibrated Peak - Observed Peak, μm	Resolution Element, μm
4.60	4.66	-0.06	0.14
8.35	8.26	+0.09	0.22
9.50	9.42	+0.08	0.25
10.77	10.77	0	0.29
11.30	11.10	+0.20	0.30
11.80	11.91	-0.11	0.31

TABLE II
FIELD OF VIEW DATA SUMMARY

Wavelength, μm	Vertical Axis, deg	Horizontal Axis, deg
4.13	0.26	0.26
10.05	0.30	0.25

TABLE III
RELATIVE SENSITIVITY OF HIGHEST GAIN CHANNEL

Wavelength, μm	G_4, v	G_3, v	G_4/G_3
4.40	2.02	0.20	10.1
4.96	2.50	0.25	10.0
5.25	2.80	0.28	10.0
5.82	3.10	0.31	10.0
6.10	3.20	0.32	10.0
6.43	3.35	0.34	9.9
10.05	3.30	0.35	9.4
12.66	2.15	0.20	10.8
14.23	1.70	0.16	10.6

TABLE IV
OFF-AXIS REJECTION

Angle, deg	Relative $\lambda = 4.96\ \mu m$	Signal $\lambda = 12.66\ \mu m$
0	1.0	1.0
1.0	5.3×10^{-1}	1.0×10^{-1}
2.0	6.9×10^{-3}	1.5×10^{-2}
3.0	4.3×10^{-3}	3.6×10^{-3}
3.0*	7.3×10^{-4}	2.7×10^{-4}
4.0	2.6×10^{-4}	2.3×10^{-5}
5.1	1.5×10^{-4}	3.1×10^{-5}
6.2	1.2×10^{-4}	2.2×10^{-5}
9.5	4.8×10^{-5}	---
11.4	3.6×10^{-5}	1.1×10^{-5}
12.8	2.5×10^{-5}	1.0×10^{-5}

*Changed from 0.1-in. aperture to 1-in. aperture.

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solar simulator						
2. Spectrometers -- Calibration						

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